A NEW STATIC RELAY
FOR EHV/UHV TRANSMISSION LINE

A Thesis Submitted
in Partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

By
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to the
DEPARTMENT OF ELECTRICAL ENGINEERING
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APRIL, 1981

CERTIFICATE

Certified that the work presented in this thesis entitled, 'A NEW STATIC RELAY FOR EHV/UHV TRANSMISSION LINE' by Mr. Yogesh Asthana has been carried out under my own supervision and that this has not been submitted elsewhere for a degree.

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ACKNOWLEDGEMENTS

I am very thankful to Dr. L.P. Singh for high valuable guidance and constant encouragement throughout the tenure of the thesis.

My thanks are also due to all my friends who helped in one or the other way in completing my thesis.

Last but not the least, I am thankful to Mr. C.M. Abraham for carefully typing this work.

YOGESH ASTHANA

ABSTRACT

A new relaying system based upon the principle of multi-input phase comparison has been designed, fabricated and tested for the transmission line protection. The system uses semiconductor circuits throughout and have high speed and good performance. The operating time of the relay is half cycle only. To detect power swing and hence subsequently blocking the tripping operation, protective circuits have been incorporated in it. The relay is capable of generating quadrilateral relay characteristics of any desired trip area to match the line characteristics properly. This operates even for a dead fault (i.e. near the relay location fault). Moreover the circuitary of the relay is simple and hence it can be fabricated easily and economically.

LIST OF PRINCIPAL SYMBOLS

$V_L = V_L\underline{/0}$	- System fault voltage, referred to voltage transformer secondary, Volts
$I_L = I_L\underline{/-\varphi}$	- System fault current, referred to current transformer secondary, Amp.
$Z = Z\underline{/\varphi}$	- Impedance seen by the relay
$Z_R = Z_R\underline{/\Theta}$	- Replica of line impedance
R	- Replica arc resistance
R_1, R_2	- Resistances for use in power-swing detector circuit
$_L$	- Impedance angle of the protected line
$K(K_1, K_2)$	- Voltage coefficient (real number $\leqslant 1$)
I	- Fault current in the arc, Amp.
V	- Nominal system interphase voltage, kV
u	- Wind velocity, km/hr.
R_F	- Fault-arc resistance.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTORY REMARKS

With the rapid increase in the demand of electrical energy and the concept of National Grid becoming a reality, it has become necessary to go for the higher voltages for the efficient and economical transfer of bulk power. Due to complexity of system with a large number of infeeds from generating stations and the requisite need for the faster clearance of faults, the use of high speed distance relays on modern system has become a reality. With the use of these high speed relays, the system can be more economically designed and the faster operation of the relay results in reduction of corona and also of burning of line conductor, which may eventually cause conductor failure.

The earliest distance relays were of electromagnetic type, which operates due to electromagnetic force produced by the magnetic flux, which in turn is produced by the operating quantity. This electromagnetic force exerted on the moving element is proportional to the square of flux in the airgap or the square of the current.

In a.c. electromagnetic relays, the electromagnetic force is given by

$$F_e = K I^2$$
$$= \frac{1}{2} K(I_{max}^2 - I_{max}^2 \cos 2\omega t)$$

where $i(t) = I_{max} \sin \omega t$ is the operating quantity and K is a constant.

The main drawbacks of this relay were unrealiable operation due to the vibration caused by the double frequency and also high burden on CTs and PTs, low torque and contact sparking etc.

In order to lower the burden of the relay, induction disc/cup type relays were later on used. The torque produced in this type of relay is due to the reaction of alternating flux with the current induced in the rotor by another alternating flux displaced in time and space but having same frequency. The torque produced is $T \,\alpha (\varphi_2 i_1 - \varphi_1 i_2)$ where fluxes φ_1, φ_2 differing in time and space induces the eddy current i_1 and i_2.

With the expansion of electrical transmission and distribution, more complex interconnected systems and the severe duty imposed upon protective gear the use of electromagnetic relays have been more or less abundant due to various reasons such as cost and difficulties in tests and maintenance etc. Because of transmission of larger amount of power at EHV/UHV voltages without loss of synchronism when short circuits are cleared in shorter time, the choice is now for static relays.

With the absence of moving parts and contacts and thus the absence of problem concerning these and also low input signals requirement and ease in maintenance and installation, the static relays are now very much used for the protection of EHV/UHV lines. The test time of such static relay is reduced due to the ease in checking of logic and trip circuit. The simplified logic approach and lower operation cost to users are additional advantages of the static relay.

1.2 PROTECTION OF TRANSMISSION LINE

The application of a particular relay is decided by its characteristics and factors like accuracy, operating time, burden etc. Accordingly different types of protection schemes are used in the system. Some of these schemes are mentioned below.

1.2.1 Over Current Relay

This relay is a single input relay with operating time tending to become asymptotic to a definite minimum value with the increase in value of current (Fig. 1). This is inherent in electromagnetic relay due to saturation of magnetic circuit. The pick up currents are adjusted in such a way that protective relay nearest the fault operates in a shorter time than the relays in succeeding sections towards the power source. However the main drawback of this relay is the shifting of balance point with the type of faults and conditions external to the system.

1.2.2 Distance Relay

This type of protection is preferred when time delay is not required. The relay compare the impedance/admittance of the line and if it is less than preset value known as replica impedance, it provides a trip signal.

1.2.3 Directional Relay

The operation of the relay is dependent upon the direction of power flow, on the basis of which fault is identified (Fig. 2). These are also used in addition to overcurrent relays for sensing the forward direction fault and also with the plane impedance relay.

The principle of operation of this relay depends upon the product of circuit current and potential. If the product is positive, torque closes the relay contacts and, if negative, it holds them apart.

1.3 DISTANCE RELAYING SCHEMES

The elementary type of distance relay compare two input quantities either in magnitude or in phase. These distance relays can be categorised into different types according to their applications.

1.3.1 Plane Impedance Relay

This measures the distance of fault by comparing the fault current I with the bus voltage V and thus provide trip signal when the measured impedance of the line upto the point

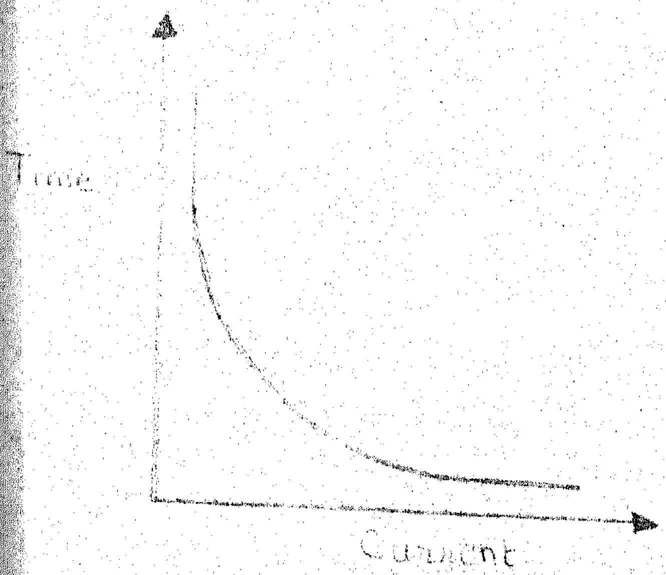


Fig 1: Overcurrent Relay

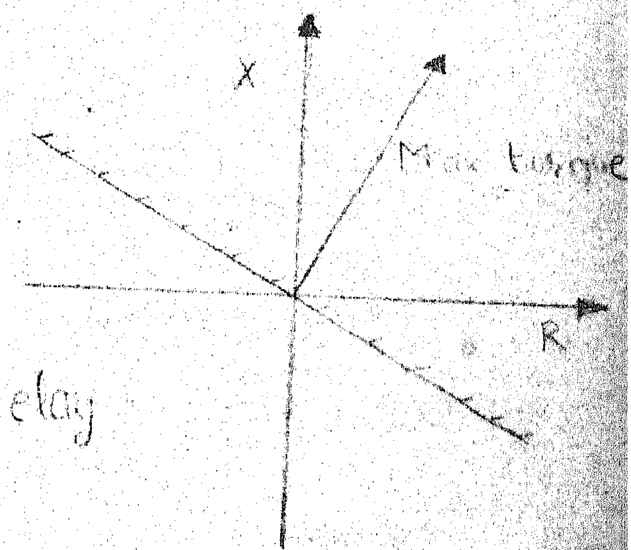


Fig 2: Directional Relay

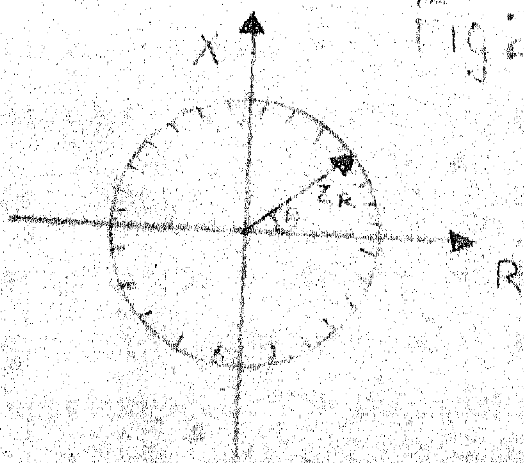
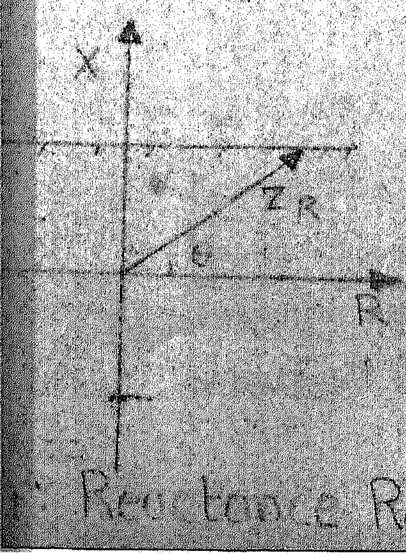


Fig 3: Plane Impedance Relay



: Reactance Relay

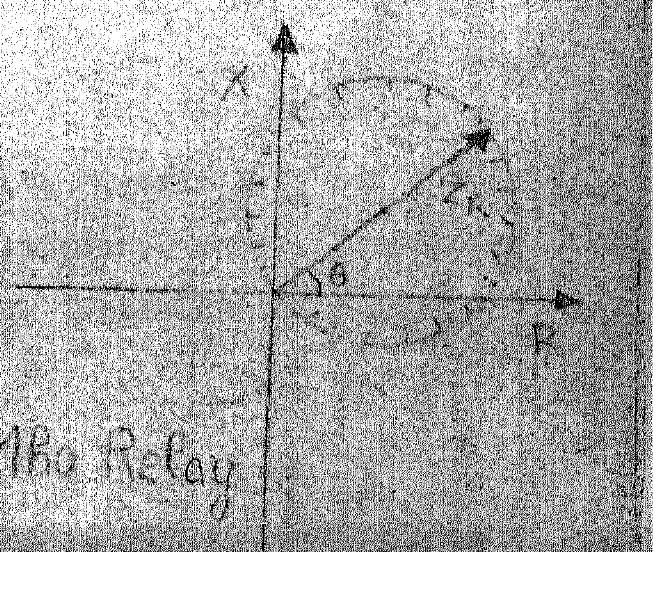


Fig 5: MHO Relay

of fault is less than the preset value of the relay i.e. replica impedance.

The input signals are

$$S_1 = I\ Z_R + V$$

$$S_2 = I\ Z_R - V$$

where Z_R is the replica impedance.

This relay trips by comparing the phase angle of input signals and the characteristics is a circle with origin as centre in R-X plane (Fig. 3). This relay is non-directional. The main drawbacks are operation of the relay due to power swing and failure of the relay due to arcing resistance.

1.3.2 Reactance Relay

The characteristics of this relay is such that it operates for any fault whose reactance from relay to fault is less than a preset value. The characteristics, when plotted on R-X plane, is a straight line parallel to X-axis (Fig. 4).

The input signals are

$$S_1 = I\ Z_R \angle 90^\circ \quad \text{i.e.} \quad I\ X_R$$

$$S_2 = I\ Z_R - V$$

Note : The relay which operates with signals $I\ Z_R$ and $I\ Z_R - V$ is known as Ohm Relay i.e. angle impedance relay. Reactance relay is a particular type of angle impedance relay with angle 90°.

This relay operates when reactance measured is less than preset value. The relay operation is not affected by the arcing resistance. The main drawbacks are the operation of relay even at normal load with high power factor and the power swing. A directional element is also required with this relay due to non-directional feature of the relay.

1.3.3 Mho Relay

The inherent advantage of this relay is to dispense away with the directional element. Its characteristics in R-X plane is circular and passes through the origin (Fig.5).

The input signals are

$$S_1 = V$$

$$S_2 = I\ Z_R - V$$

This relay operates when the admittance of the line is less than preset value. This relay is immune to power swing and also arcing resistance. The main drawbacks are failure for faults at the bus or at the balance point.

1.3.4 Offset Mho Relay

In order to have relay operation for nearby faults in the reverse direction, a certain offset is given to mho relay.

The input signals are

$$S_1 = I\ Z_2 + V = K\ I\ Z_R + V$$

$$S_1 = I\ Z_R - V$$

where $Z_2 = K\ Z_R$ and K is a fraction.

The characteristics we get, is an offset circle in R-X plane (Fig. 6) and this offset mho relay is used for the purpose of starting timer motor and also carrier signals in the case of carrier pilot relaying.

1.4 PRINCIPLE OF DEFINITE DISTANCE SCHEME

As the principal shortcomings of high speed overcurrent element is the shifting of balance points with the type of faults and also with the conditions external to the protected section such as change in Generating Capacity or putting in or out of transmission lines, we use distance relays. These type of relays are in general free from above mentioned drawbacks.

The first element of the relay reaches 80 to 90 percent of the length of protected section (Fig. 7). The second element reaches to about 50 percent of the length of next section and thus serves to clear the end zone faults on the protected section and also to give a backup protection to the nearer half of the next section after a certain time delay. The third element reaches the end of next section and thus provides backup protection to the remaining portion of that section after a certain time delay. Such relays can be arranged for measuring impedance or reactance and these are provided normally with a built-in directional feature.

A simple circuit of a 3-zone plane impedance protection scheme is mentioned in Fig. 8. Here D is a contact of

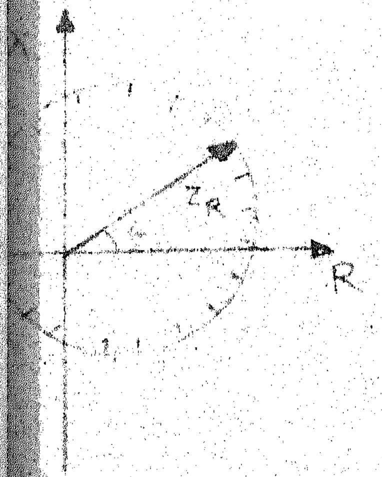


Fig 6: Offset Relay

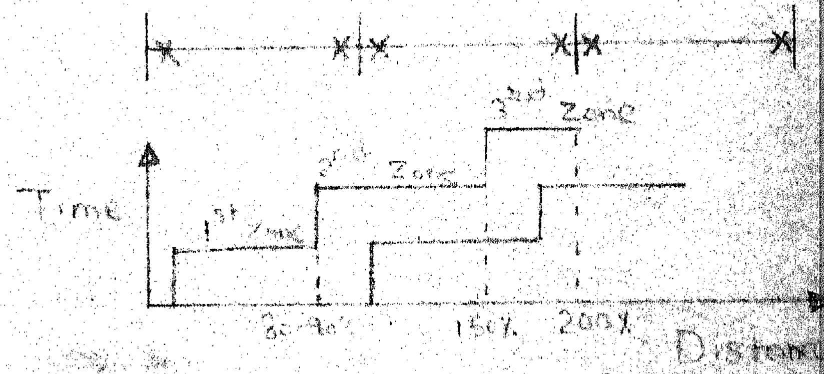


Fig 7: Three zone protection

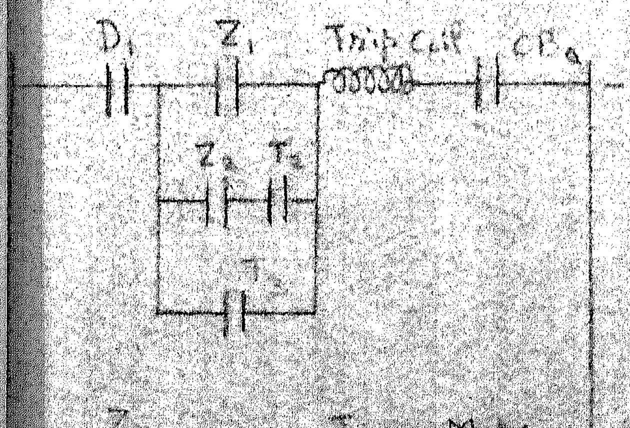


Fig 8(a)

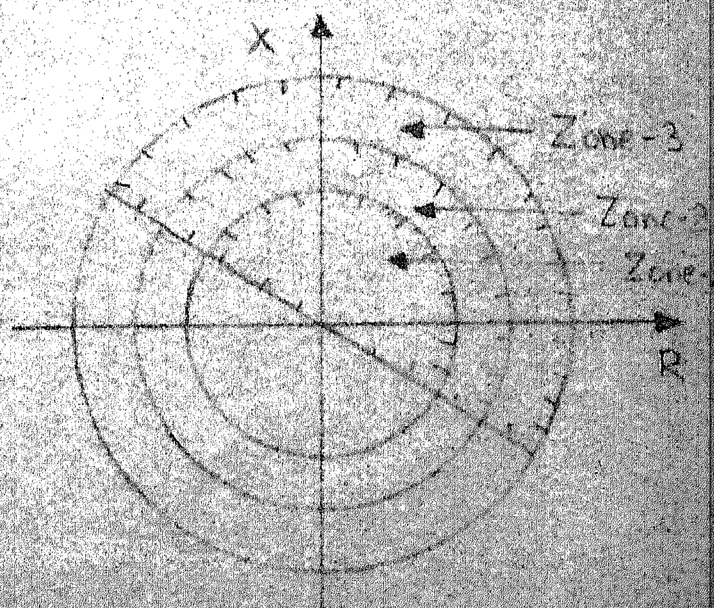


Fig 8 (b)

Three-zone plane Impedance protection Scheme

directional unit; Z_1, Z_2, Z_3 are contacts of zones 1,2 and 3 elements; T_2, T_3 are timer contacts and CB_a is an auxiliary contact on the circuit breaker.

The zone 1 element operates without any intentional time delay but zone 2 and zone 3 elements Z_2 and Z_3 operates with a time delay of T_2 and T_3 respectively. Z one 3 element Z_3 controls the operation of timer motor and thus serves as a starting element for the protection scheme.

CHAPTER 2

RELAYING SCHEMES FOR EHV/UHV LINES

2.1 INTRODUCTION

The protection scheme of EHV lines are based on phase, amplitude, composite or instantaneous comparison techniques. In order to protect transmission lines, various schemes are used such as 3-zone protection by polarised mho relay, combination of reactance-mho relay or using the concept of quadrilateral or conic characteristics, which matches with the faulted line parameters. Based upon the comparison technique of input signals, we can have different types of relay. These are mentioned below.

2.2 PHASE COMPARATOR RELAY

The principle of operation of these type of relays depends on the phase difference between the input signals and thus the output is independent of input signals magnitude, These may be sine, cosine comparators and with the help of phase comparison technique, we can get quadrilateral, 3-zone mho relays etc. Some of these are mentioned below.

2.2.1 3-Zone Mho Relay

The characteristics of this relay in R-X plane is shown in Fig. 9.

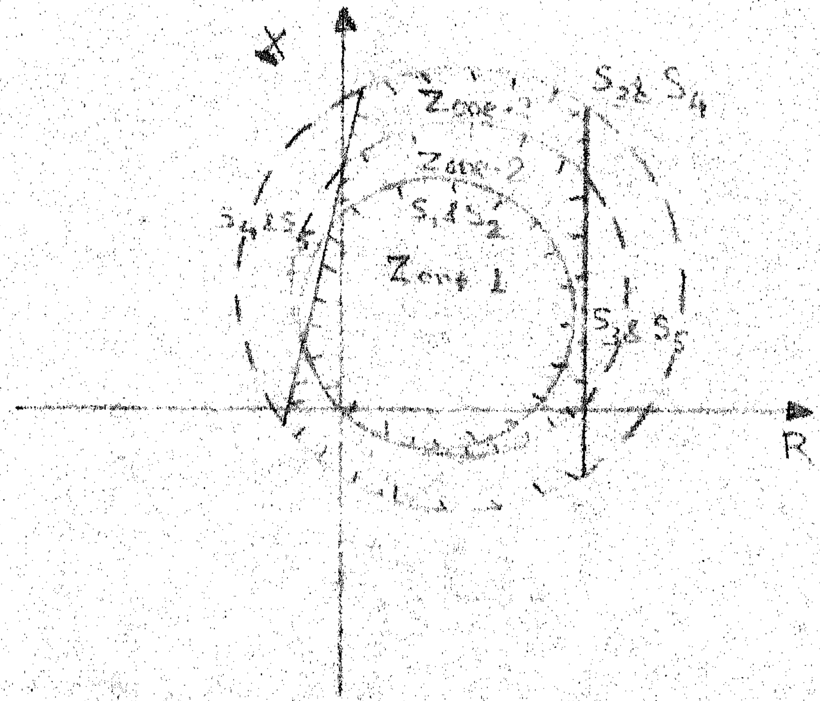


Fig 9: 3-zone Mho Relay

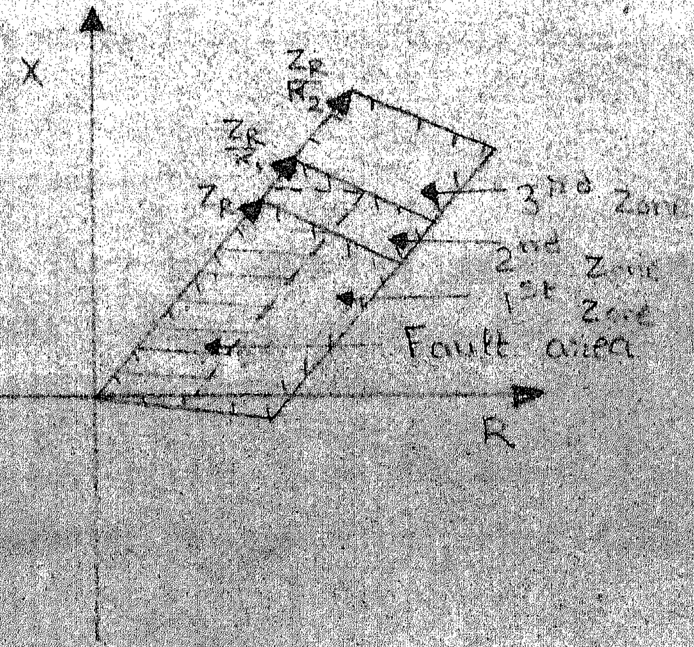


Fig 10: 3-step Distance Relay

The input signals are

$$S_1 = -K_1 \angle\alpha_1 \; V_L + I_L Z_{R1} \underline{/\theta_1 - \varphi_L}$$

$$S_2 = K_2 \angle\alpha_2 \; V_L$$

$$S_3 = -K_3 \angle\alpha_3 \; V_L + I_L \; Z_{R3} \underline{/\theta_3 - \varphi_L}$$

$$S_4 = K_4 \angle\alpha_4 \; V_L + I_L \; Z_{R4} \underline{/\theta_4 - \varphi_L}$$

$$S_5 = I_L \; Z_{R5} \underline{/\theta_5 - \varphi_L}.$$

where $K_1 \angle\alpha_1$, $K_2 \angle\alpha_2$, $K_3 \angle\alpha_3$, $K_4 \angle\alpha_4$ and $K_5 \angle\alpha_5$ are the constants for the relay.

In this relay using the principle of phase comparison, signals S_1, S_2 provides mho characteristics for zone 1 and 2; S_4,S_5 and S_3,S_5 provides the blinders while S_3,S_4 provides composite characteristics for zone 3. The drawbacks are sluggish relay operation over boundary faults and need to have proper time coordination for relaying, which increases the response time.

2.2.2 3-Step Distance Relay

This uses the discrete components for the different functional blocks and thus it is suitable for long and heavily loaded lines for all types of faults.

The polar characteristics (Fig. 10) obtained is compatible with the fault characteristics and thus relay is immune to the

power swing and can be designed for the use with either carrier current or microwave pilot. The main drawback in the relay is the use of auxiliary transformer with multitappings.

2.2.3 Digital Phase Comparator Relay

In this relay, use of a digital up/down counter fed with constant frequency pulses is done. The net count at the end of each cycle is taken as trip condition if it is positive i.e. up counting is greater than down counting period. No trip is there when up counting is less than down counting period. As this counter reset every halfcycle, the period of operation is one cycle.

The main drawbacks are sensitivity of TTL gates to the spurious signals i.e. transients and the line disturbances.

2.2.4 Quadrilateral Characteristics Relay

The quadrilateral characteristics (Fig. 11) is used for the proper matching of the fault area and thus it prevents the false tripping of the relay.

The four input signals required are

$$S_1 = I\ Z_1 \underline{/\theta_1 - \varphi} - K_1 \underline{/\alpha\ V}$$

$$S_2 = I\ Z_2 \underline{/\theta_2 - \varphi}$$

$$S_3 = I\ Z_3 \underline{/\theta_3 - \varphi}$$

$$S_4 = K_4 \underline{/\alpha_4\ V}$$

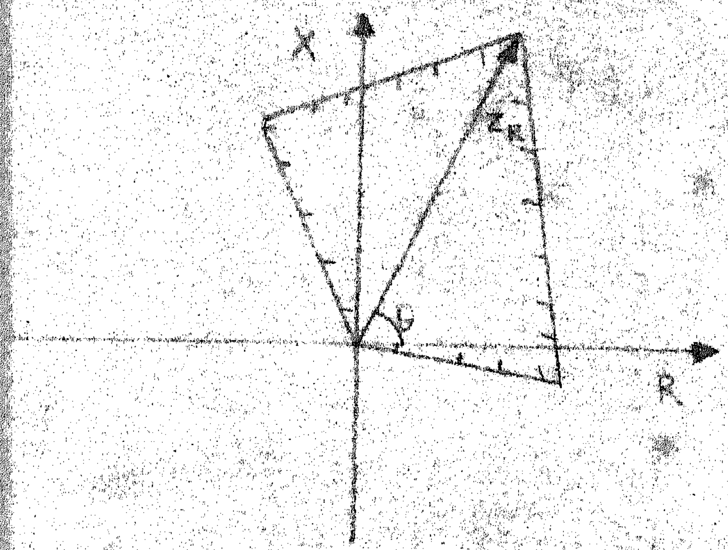


Fig 11: Quadrilateral Relay

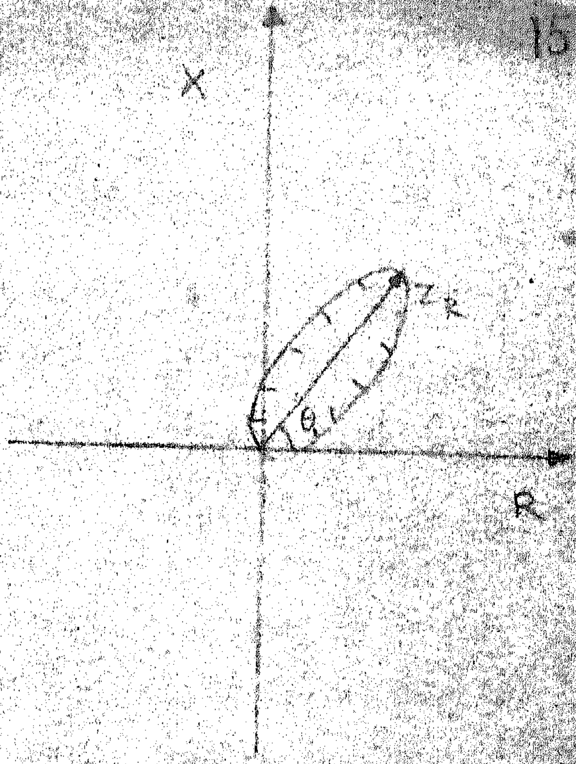


Fig 12 (a): Elliptical Relay

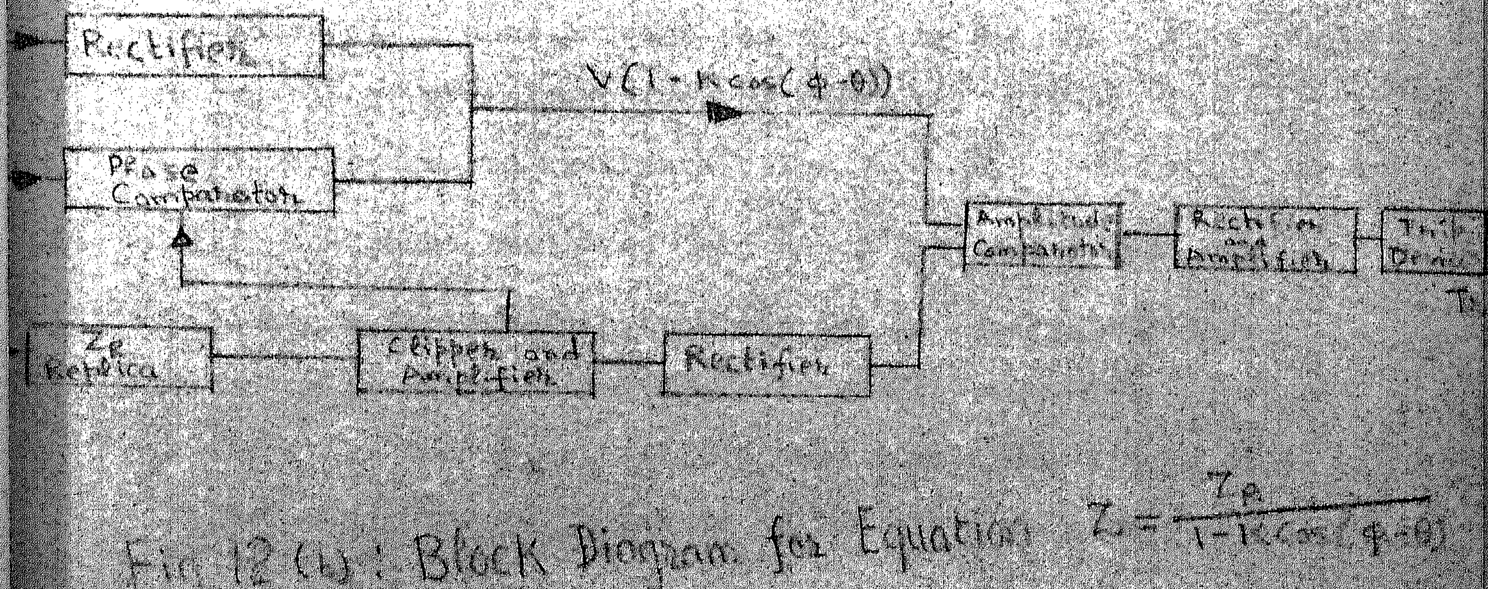


Fig 12 (b): Block Diagram for Equation $Z = \frac{Z_R}{1-K\cos(\phi-\theta)}$

For the proper enclosure of fault area $Z_2 = X_R$, $Z_3 = R_R$ and $Z_1 = R_R + jX_R = Z_R$, where Z_R is the replica impedance.

The signals S_1, S_3 and S_3, S_4 provides the directional characteristics; S_1, S_2 provides angle impedance (i.e. a reactance) characteristics and interaction of S_1, S_4 causes the mho characteristics. This mho circle will not interfere with rectangular tripping area if $Z_R = R_R + jX_R$ as the circle of diameter Z_R goes through the corners of the rectangle bounded by R_R and X_R. Tripping occurs if all the equations resulting from comparison of all the inputs in pairs are simultaneously satisfied for the length of time set by the delay unit.

2.3 AMPLITUDE COMPARATOR RELAY

This relay operates when the magnitude of operating signal is greater than restraining signal by a predetermined critical value. In ideal condition, output is independent of the phase difference between the relaying signals. This relay is capable of giving any type of threshold characteristics. A typical scheme is mentioned below.

2.3.1 Polyphase Amplitude Comparator Distance Relay

When a fault occurs, the current in the faulted phase conductor or pair of conductors is greater than the current in any other conductor. At the same time, the voltage of the faulted conductor to ground or to the other faulted conductor

is the lowest. Hence the measurement of correct impedance to fault requires a comparator, which automatically compares the highest current with the lowest voltage. This operates when the measured impedance is less than the replica impedance of the line.

2.4 HYBRID COMPARATOR RELAY

This relay operates on the principle of combination of phase and amplitude comparators, wherein one type of comparator is supplied with one of its inputs from a comparator of the other type. This is necessary when input signals are related by a polar equation

$$Z = \frac{Z_R}{1 - K\cos(\varphi - \theta)}$$

This is a general equation for the conic characteristics with $K < 1$ an ellipse, $K = 1$ a parabola, $K > 1$ an hyperbola or a circle with $K = 0$.

The input signals necessary for obtaining the elliptical characteristics (Fig. 12) are

$$S_1 = I\, Z_R$$

$$S_2 = V$$

$$S_3 = KV \cos(\varphi - \theta)$$

The signals S_1, S_2 are fed directly to the amplitude comparator along with a cosine term obtained from an auxiliary phase

comparator, which uses voltages I Z_R to polarize the line voltage V. The relay operates according to the amplitude comparator principle.

CHAPTER 3

BASIC COMPONENTS OF STATIC RELAY

3.1 INTRODUCTION

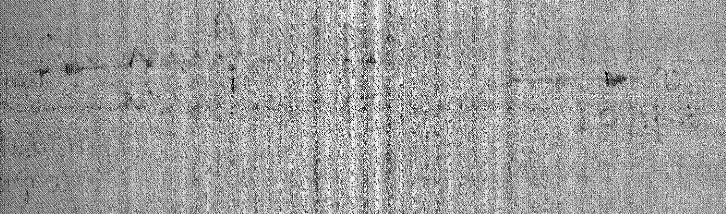
Integrated circuits have added ease, accuracy and freedom of design in relaying circuit. This chapter is devoted to show, in brief, that I.C. can carry out basic functions of protective relaying in an effective manner.

3.2 APPLICATION OF INTEGRATED CIRCUITS

Some of the basic functions of protective relaying that can be carried out using the integrated circuits are mentioned below.

3.2.1 Amplitude Comparator

Linear I.C. comparator can be used for very accurate amplitude comparison down to a few mV level. Fig. (13) shows a typical amplitude comparator circuit using a linear I.C. comparator. The operating signal is applied to one terminal of comparator and the restraining signal to the other terminal. When the operating signal increases in magnitude to the restraining signal, the output level of comparator changes its state. Due to the high internal gain and negative feedback employed in the linear I.C. comparator, the accuracy obtained is very high.



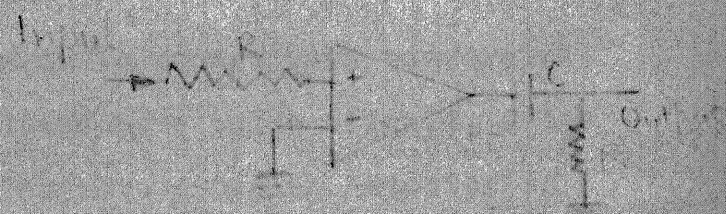
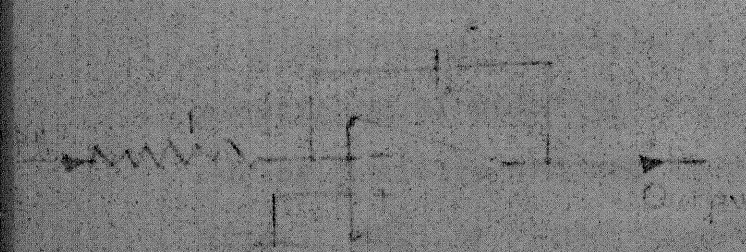


Fig 13: Amplitude Comparator

Fig 14: Zero Crossing Detector



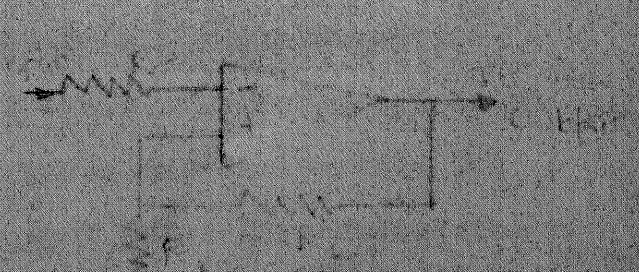


Fig 15: Integrator

Fig 16: Level Detector

3.2.2 Zero Crossing Detector

It basically involves the sine to square wave conversion by a level detector circuit followed by a pulse circuit, which consists of a differentiator. The zero crossing detector is associated with the production of a pulse at the particular zero crossing. Fig. (14) shows the circuit for zero crossing detector.

3.2.3 Integrator

Inverse time overcurrent relays and blocking average type of comparator work on the basis of integration. A linear I.C. integrator is shown in Fig. (15). The output voltage of a integrator is a linear function of the product of input current and time. The accuracy of I.C. integrator is very high due to its large internal gain and high input impedance.

3.2.4 Coincidence Comparator

Operating principle of many relays depends upon the occurrence of polarity coincidence of all input signals during positive and negative half cycle of a reference input signal 'AND' or 'NOR' digital IC gates are best suited for the purpose. 'AND' gate gives output pulse for coincidence during positive half cycle of the reference signal and 'NOR' gate gives output pulse for the coincidence in the negative half cycle period.

3.2.5 Level Detector

Linear IC can be used as level detectors for application as amplitude comparators. A Schmitt trigger circuit arrangement is shown in Fig. (16).

Using the above basic circuits and new relaying principles, several static relays have been developed and their performance have been tested.

CHAPTER 4

A NEW STATIC RELAY FOR EHV/UHV TRANSMISSION LINE

4.1 INTRODUCTION

For the fast protection of transmission line against all types of faults, a new high speed static distance relay has been designed. This relaying scheme uses I.C. components for the measuring, discriminating and the logic operations. Trip signal may be given to the thyristor, which energises the trip coil of the circuit breaker and thus it operates the breaker.

From the fig. (17), it is also apparent that this relay, is less suceptible to the maloperation under power swing conditions as compared to the 3-step mho relay. The characteristics of the static relay can be set to cover only the fault area of the line to be protected. As there are some cases, when the system can recover even after the severe power swing, in this relay arrangement is made for blocking the operation for the preassigned number of pole-slipping cycles without really affecting the normal relay operation under fault condition. Moreover, the use of blinders or elliptical threshold characteristics are made for preventing the operation of relay on overload or power-swing conditions.

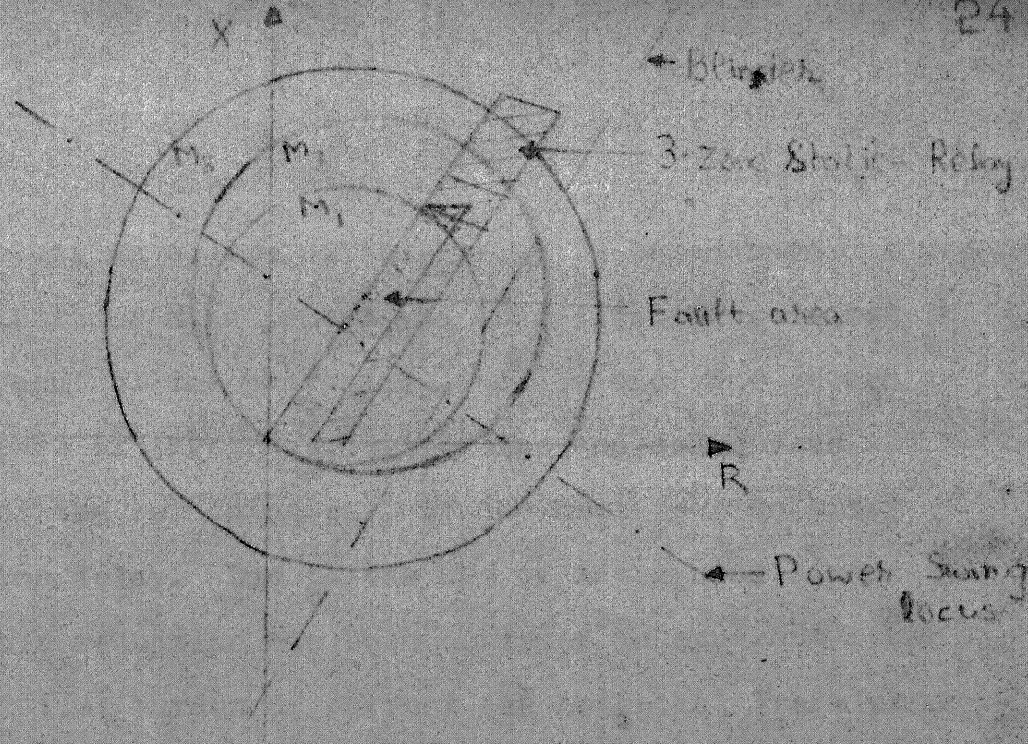


Fig 17: Typical Characteristics of 3-step Mho and Static Distance Relay

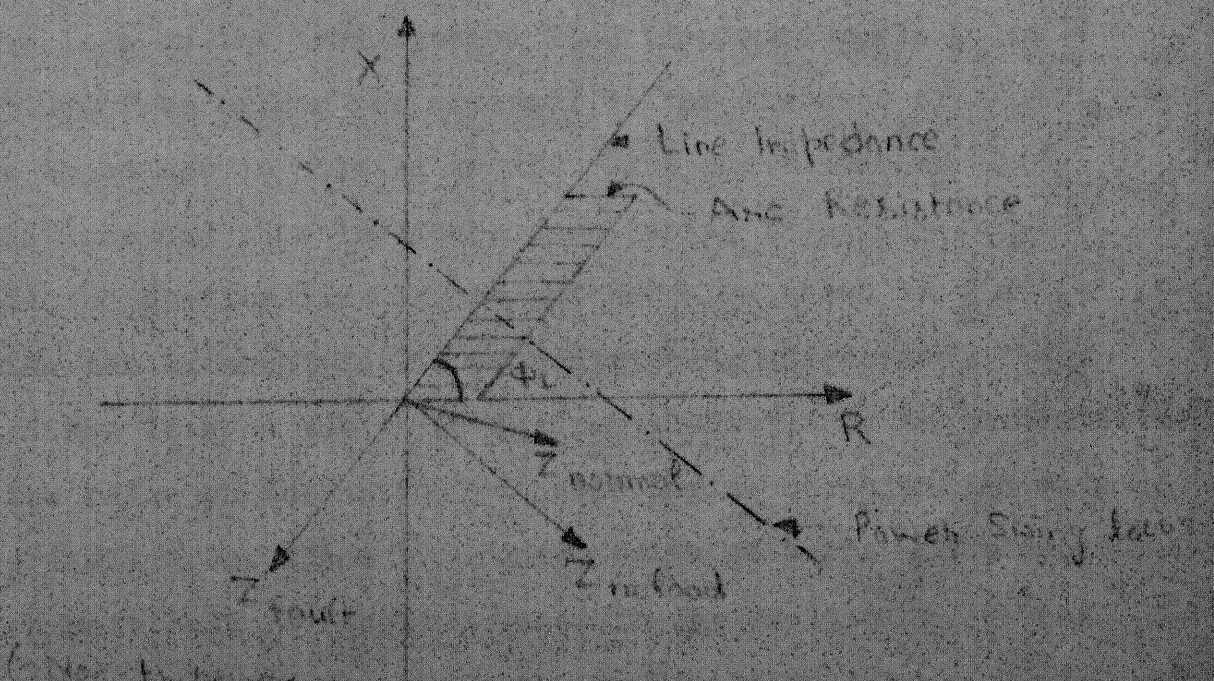


Fig 18: Impedance at terminal of Distance Relay

The protection scheme of this relay is based upon 3-zones of distance measurement and thus first zone is set to cover 80 percent of the protected line, second zone covers next 50 percent of the transmission line and third zone takes care of the remaining part of the next section after a certain time delay. Due to the use of integrated circuits, a considerable reduction has been achieved in apparent power requirements i.e. burden of current and potential transformer circuits.

4.2 PRINCIPLE OF OPERATION

During an internal short circuit on the faulted phase of the transmission line, the impedance seen by the distance relay lies on the transmission line impedance angle φ_L at a distance from origin proportional to the distance of fault. This impedance is shifted to the right due to the arcing resistance and thus impedance seen during the fault on a protected section lies in the hatched area shown in fig. (18). During the external faults in nontripping direction, the impedance lies on the third quadrant. Similarly impedance seen by the relay on the unfaulted phase during a fault lies outside this fault area. Thus by proper design of a phase detector, which acts only for the impedance in the fault area, we can have a protective scheme for the transmission line.

4.2.1 Basic Phase Detector Principle

This phase detector uses the principle of coincidence. The line voltage and currents are applied to the measuring circuit, which provides the signals $I_L Z_R$, $I_L R - V_L$ and $V_L \underline{/-90^\circ}$. $I_L Z_R$ signal is applied to a pulse shaping circuit, which produces the sampling positive pulses at every half cycle i.e. at the instant when voltage $I_L Z_R$ changes from positive to negative and also when it changes. From negative to positive. This sampling pulse is then applied to a phase detector, which is an 'AND' gate. The pulse will appear at the output of the gate, only if, at the time of appearance of the pulse, all the three input voltages $I_L R - V_L$, $V_L \underline{/-90^\circ}$ and V_L coincides i.e. becomes all positive or negative together (Fig. 19).

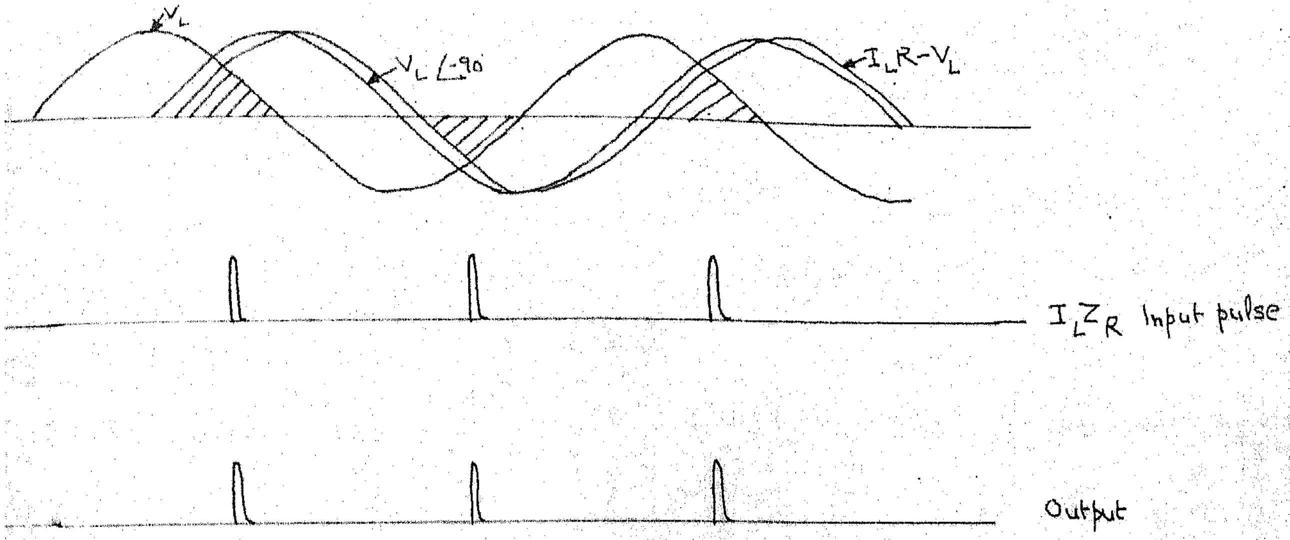
The logical coincidence of pulse $I_L Z_R$ and $V_L \underline{/-90^\circ}$ provides a directional pick up characteristics (Fig. 20) and the operating criterian can be given as

$$(\theta - 90^\circ) < \varphi < (\theta + 90^\circ)$$

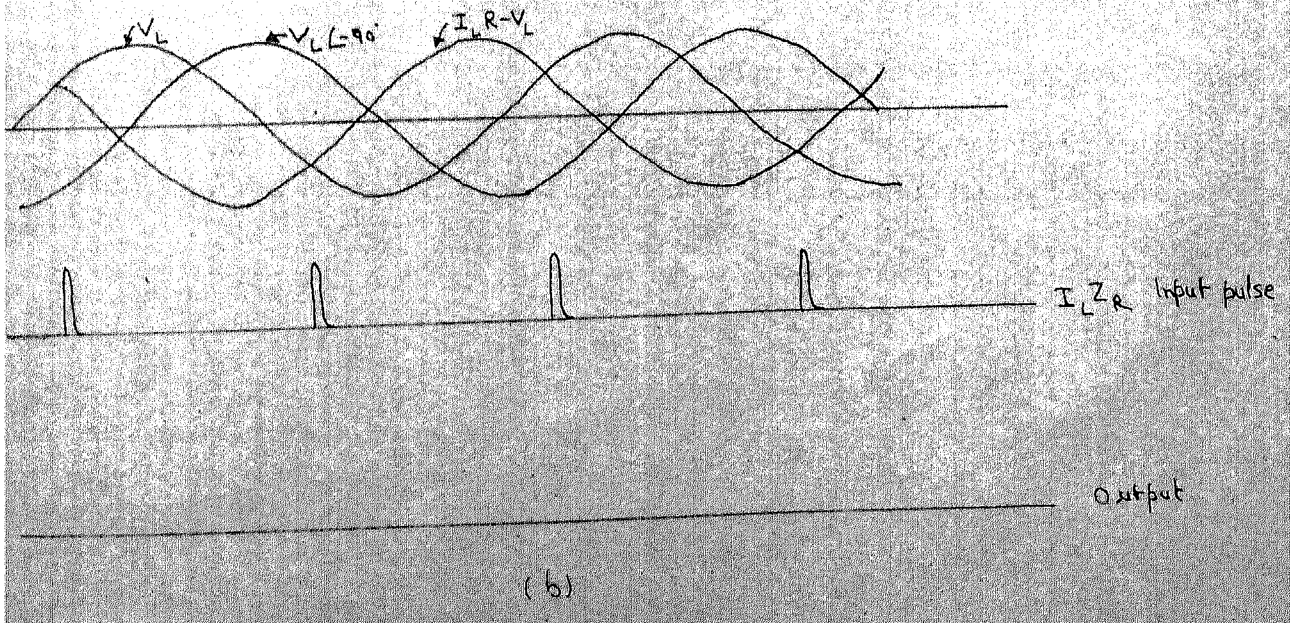
Similarly a blinder characteristics (Fig. 21) is obtained by the pulse $I_L Z_R$, $I_L R - V_L$ and V_L inputs. The operating criterian can be given as

$$\underline{/V_L} < \theta < \underline{/V_L - I_L R}$$

Thus the combination of above two logical coincidence operation gives a variable phase comparator with improved polar characteristics in R-X plane.



(a)



(b)

Fig 19: Waveform of Phase Detector "And" gate

(a) Fault in tripping direction

(b) Fault in non-tripping direction

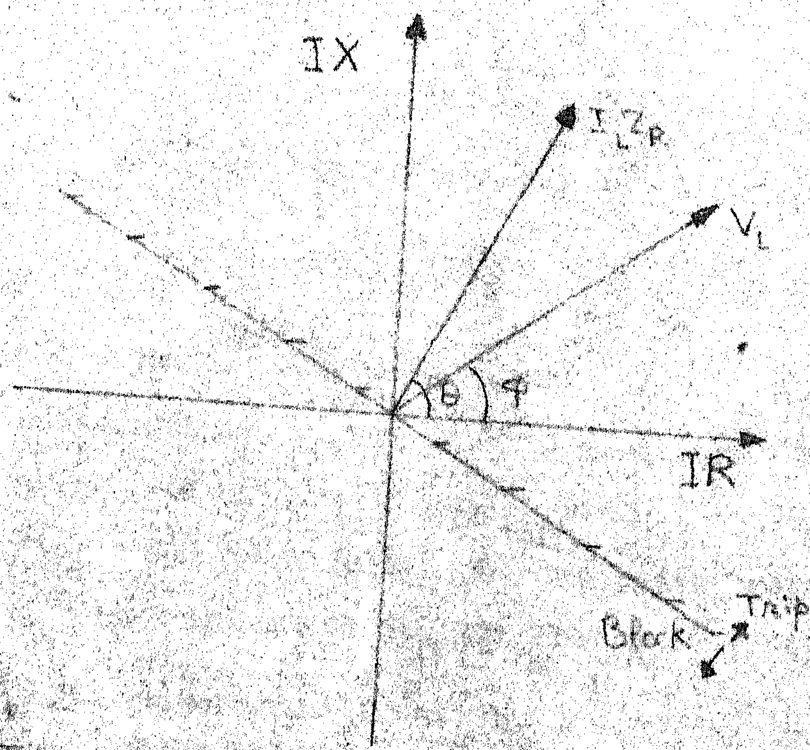


Fig 20: Directional Relay Characteristics

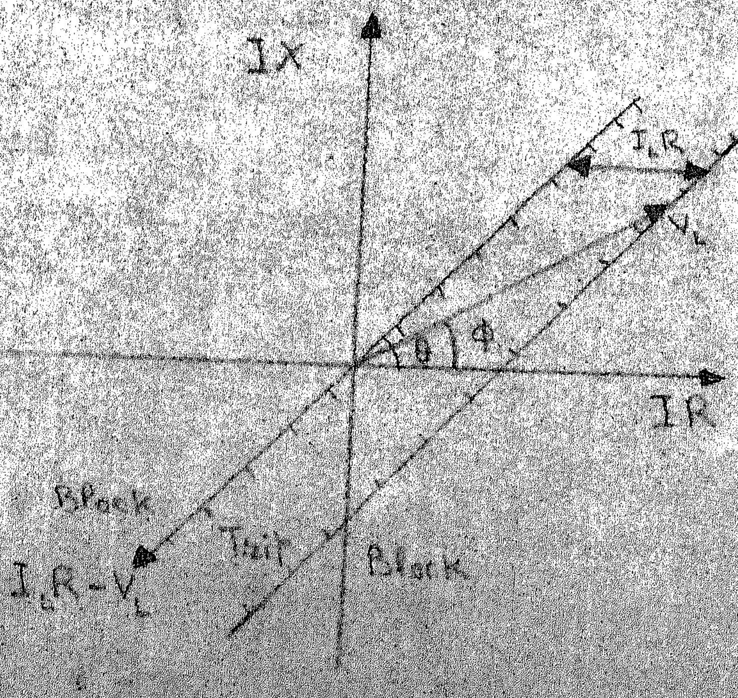


Fig 21: Blinder Characteristics

4.2.2 Zone Differentiation Circuit

The sampling pulse output of the phase detector is applied to zone differentiation circuit, which provides the selective operation of the relay according to the three zone measurement. For zone-1 reach, zone-1 'AND' gate provide the signal to trigger an output via an 'OR' gate. Similarly, for zone-2 and zone-3 reach, the respective gates operate after a set time delay. Hence, relay provides fast and selective operation for the transmission line.

4.2.3 Power Swing Blocking

The main difference between a power swing and a fault is the slow variation of current and voltage of the system. Hence the change in impedance, i.e. swing impedance locus is gradual. As in the case of fault, the rate of rise of current is instantaneous, the impedance seen by the relay changes very quickly from a normal load value to a fault value. So, we can distinguish a power swing from a fault in the system.

4.3 COMPLETE RELAY CIRCUIT

4.3.1 Block Diagram of the Relay

A block diagram of the complete relay is shown in the fig. (22). The input signals I_L and V_L provides the phase comparator inputs $V_L \underline{/-90^{o}}$, $I_L R - V_L$ and $I_L Z_R$ through the measuring circuit. The power swing detector differentiates a

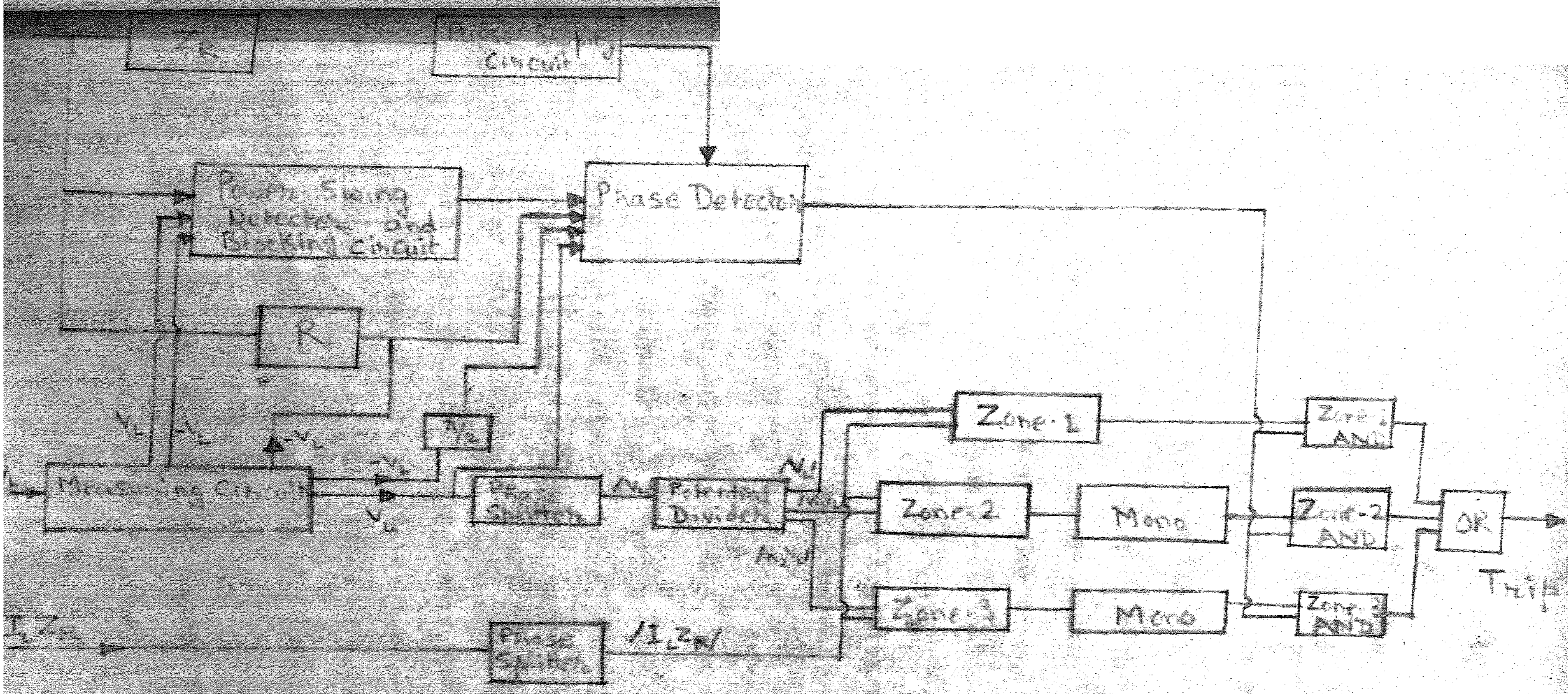


Fig 22: Complete Relay

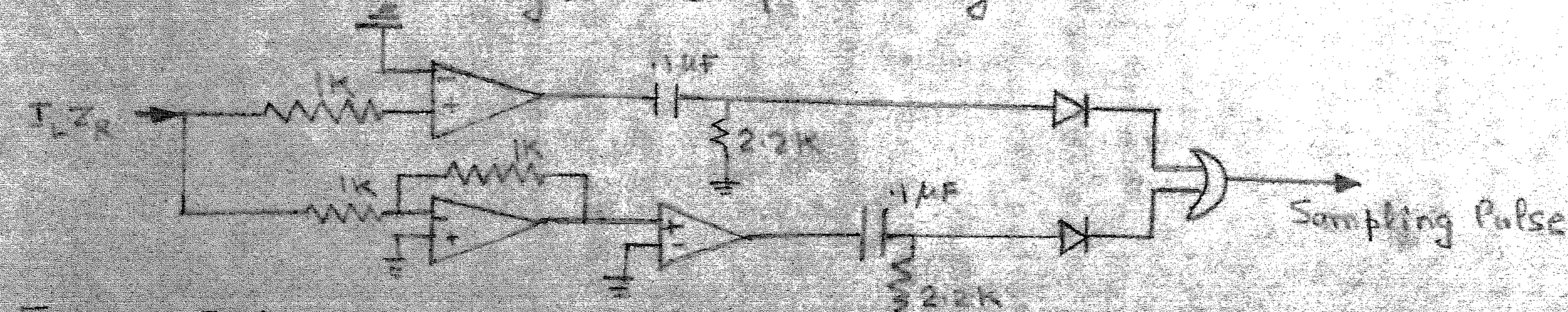


Fig 23: Pulse Shaping Circuit

power swing from a fault and accordingly it gives a signal to the phase detector. After the phase detector, the sampling pulse is given to the zone differentiation circuit and this provides the selective operation of the relay.

4.3.2 Pulse Shaping Circuit

The signal $I_L Z_R$ is fed to the zero crossing detector, which provides rectangular signal from the sinusoidal $I_L Z_R$ (Fig. 23). This rectangular signal is passed through R-C differentiator and diode combination, which gives a positive pulse at the time of $I_L Z_R$ going from zero to positive value. Similarly we obtain another positive pulse at the time of signal $I_L Z_R$ going to negative value from zero position. These two positive pulses are combined using an 'OR' gate.

4.3.3 Phase Detector Circuit

The signals $I_L R - V_L$, $V_L \underline{/-90^o}$ and V_L are passed through zero crossing detector and after clipping their negative values, these signals are 'ANDED' (Fig. 24). A signal from power swing detector is also applied to this output signal such that we get an output only when all inputs $I_L R - V_L$, $V_L \underline{/-90^o}$ and V_L are positive, i.e., we check the positive coincidence and also the absence of power swing.

Similarly, we obtain the output signal for the case when all the three signals $I_L R - V_L$, $V_L \underline{/-90^o}$ and V_L are negative i.e. we check the negative coincidence.

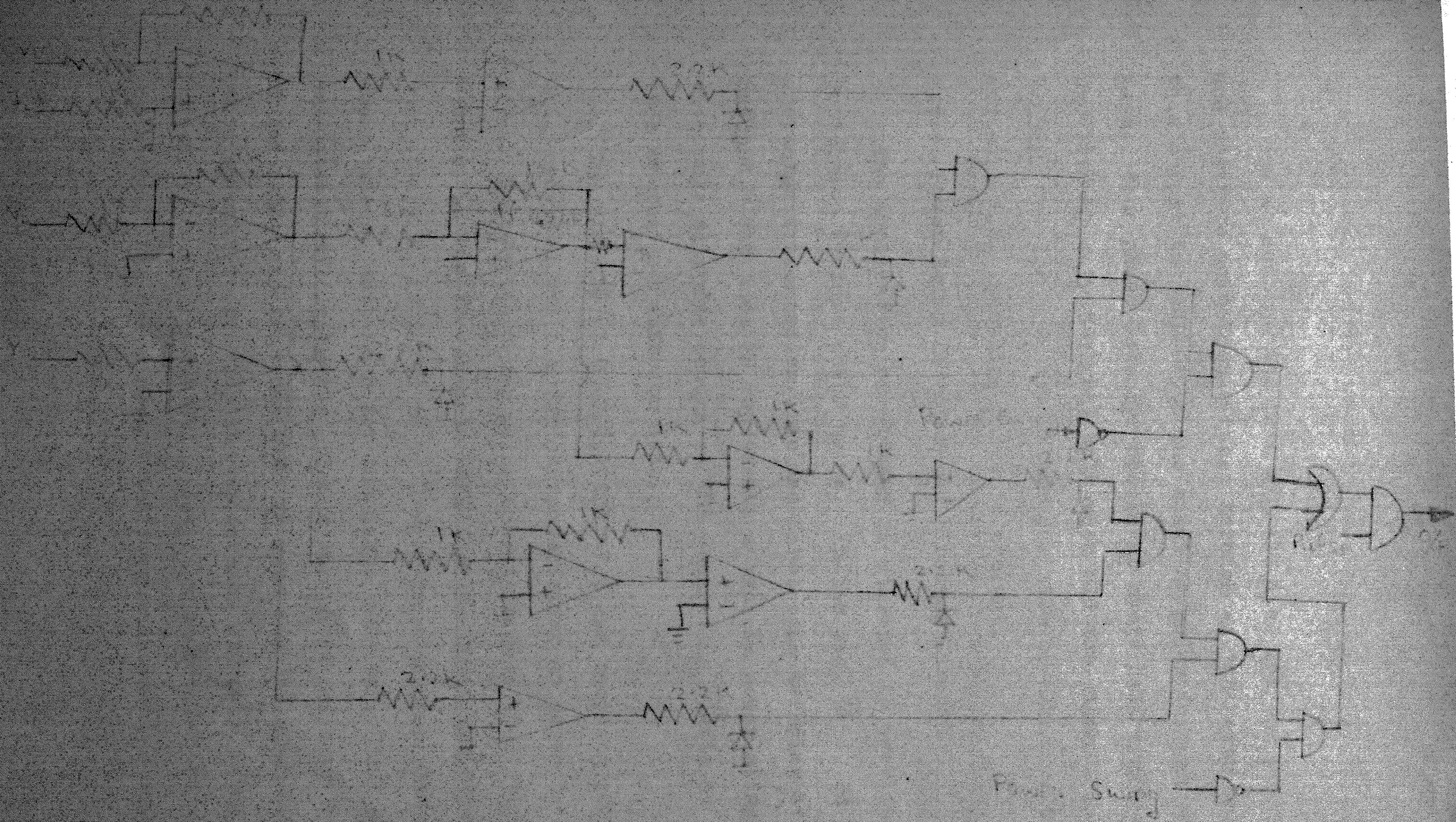


Fig 24: Phase Detector Circuit

Now we combine the both signals i.e. for the positive and negative coincidence cases through an 'OR' gate and then this output is 'ANDED' to the sampling pulse through an 'AND' gate. Thus phase detector checks at every half cycle and provides an output signal only when all the signals V_L, $V_L\underline{/-90^{\circ}}$ and $I_LR - V_L$ are either positive or negative together and also I_LZ_R sampling pulse is present.

4.3.4 Power Swing Detector and Blocking Circuit

The application of blinder is utilized to provide protection against power swing. In the fig. (25), OA is the protected transmission line and first zone tripping area is hatched. The line MN represents a typical power swing locus, when pole slipping occurs in the generating plants at the ends of the transmission line.

The signals $(I_LR_1+V_L)$, $(I_LR_2-V_L)$ and sampling pulse I_LZ_R provides the blinder characteristics as shown in fig. (26). To provide power swing operation even when fault is absent, we use the signal 'NAND' of the phase detector. The resistance R_2 is taken to be larger than maximum arcing resistance setting R for the phase detector. The use of monostable multivibrator blocks the phase detector for a fixed delay and this can also be used for the alarm-annunciation circuit to provide the indication of power swing presence. The operation of power swing detector is similar to phase detector. The principle of positive and negative coincidence

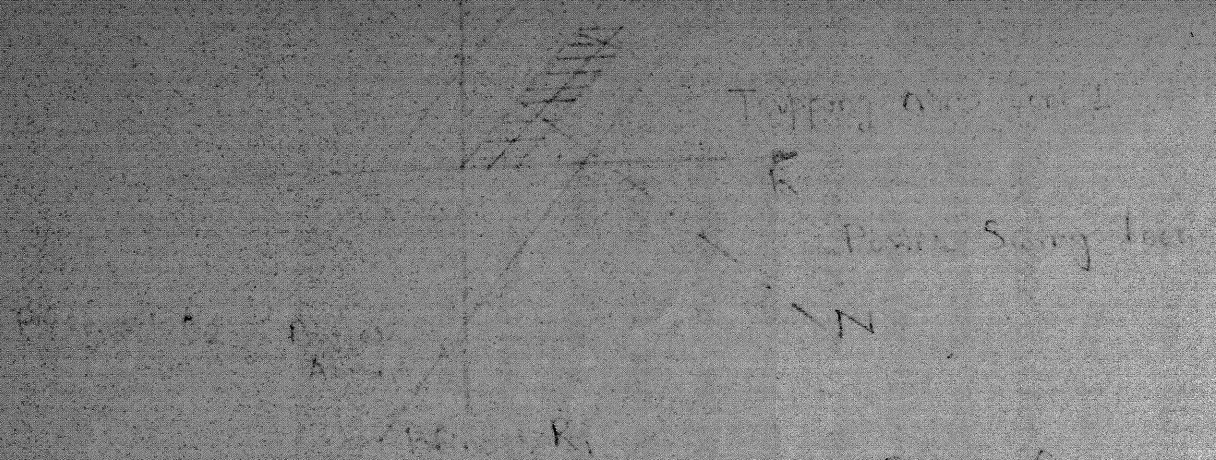


Fig 2.5: Application of Blinder for Power Swing

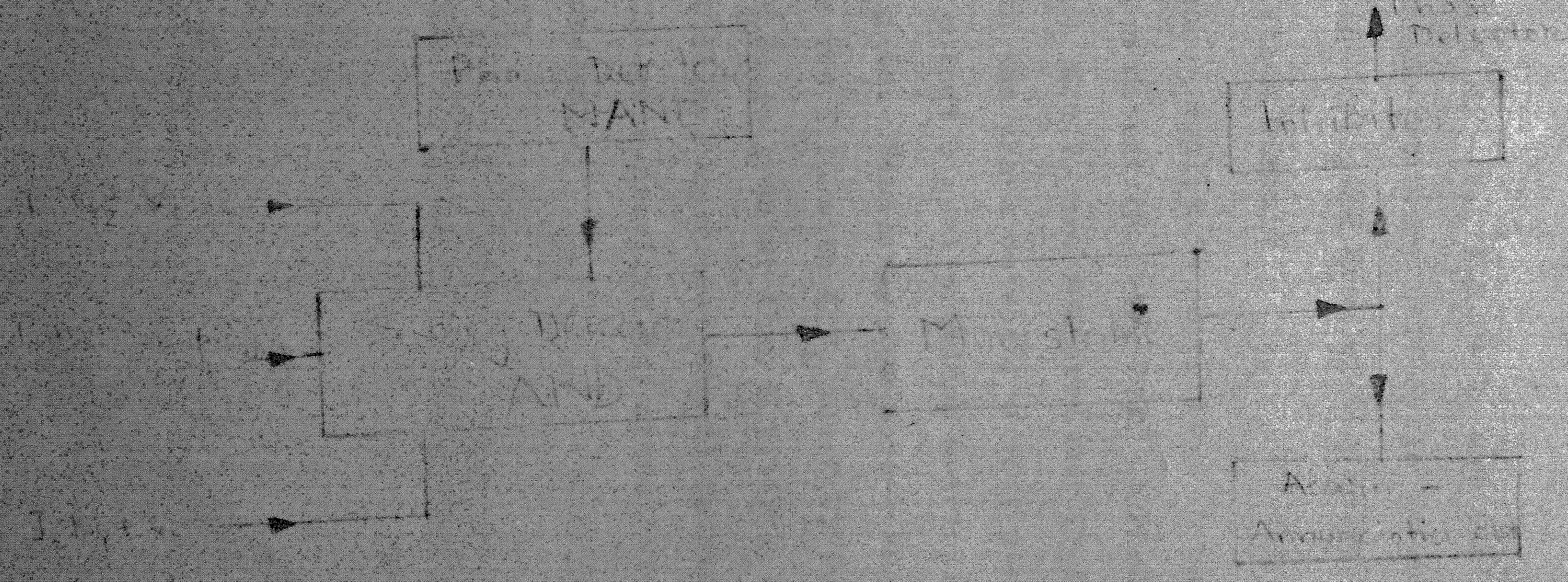


Fig 2.6: Power Swing Detector and Blocking

is used for the signals $I_LR_1 + V_L$, $I_LR_2 - V_L$ and the sampling pulse I_LZ_R. Thus it checks at every half cycle as whether power swing is within the tripping area of the relay or not.

4.3.5 Zone Differentiation Circuit

The instantaneous amplitude comparator is used for the zone differentiation operation (Fig. 27). For zone-1 protection, signals I_LZ_R and V_L are compared and if I_LZ_R is greater than V_L with the phase detector output signal is also present, then an output signal provides a tripping operation via an 'OR' gate. Similarly for zone-2 and zone-3 operation, we compares the I_LZ_R with K_1V_L and K_2V_L respectively. If the signal I_LZ_R is greater than K_1V_L or K_2V_L, then after a fixed set delay, an output signal is provided for tripping via an 'OR' gate provided the phase detector output pulse is also present.

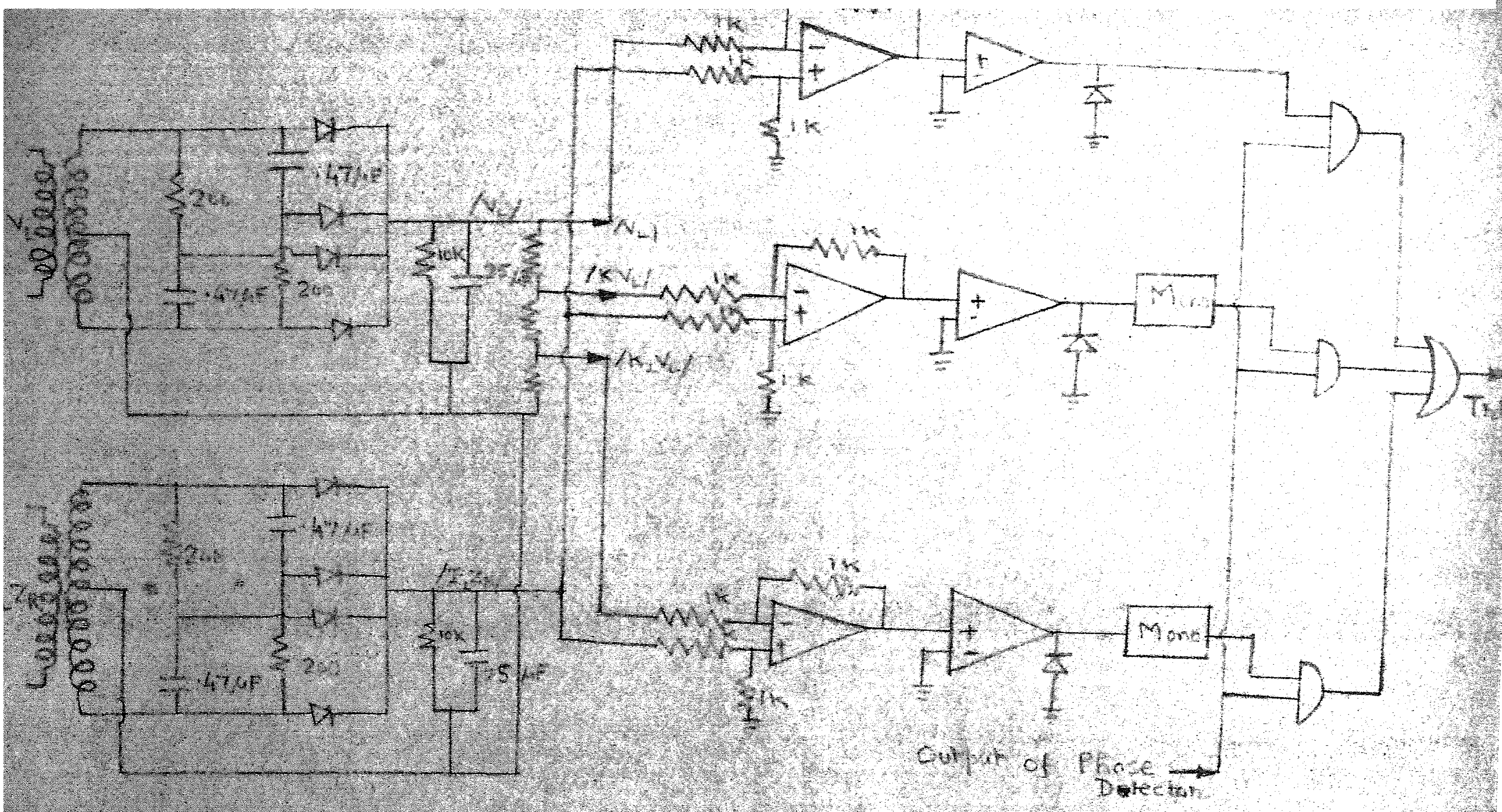


Fig 27: Zone Differentiation Circuit

CHAPTER 5

CONCLUSION

5.1 STEADY STATE TESTING

For the steady state testing, line voltage is taken as reference voltage $I_L R$. Signals V and $I_L Z_R$ are obtained by using phase shifting bridges. $I_L Z_R$ is given a desired magnitude and phase shift. Signal V is set for a particular phase shift and its magnitude is varied to locate the boundary of the trip region.

The Relay Characteristics shown in Fig. 28 and Fig. 29 are obtained by choosing $\varphi_L = 45^{\circ}$. The results of the test are given in tables 1 and 2. It can be shown that reach in $I_L Z_R$ or $I_L R$ direction is increased by increasing the values of Z_R or R respectively.

5.2 CONCLUDING REMARKS

A new relaying system has been designed, fabricated and tested for the transmission line protection. Based upon the operation and steady state testing results, the following conclusion is derived.

(i) The relay is capable of generating quadrilateral relay characteristics of any desired trip area. The phase angle of Z_R is properly choosen to match that of the line impedance. Such a choice makes voltage $I_L Z_R$ transient free and also an excellent reference voltage.

Table 1

Quadrilateral Steady State Relay Characteristics using $\varphi_L = 4.5^{\circ}$ for two Values of Z_R

Angle φ_{degree}	Critical Value of V for Z_{R1} in volts	Critical value of V for Z_{R2} in volts
0	2.0	2.0
14	2.8	2.5
18	3.6	3.0
23	3.8	3.3
30	4.0	2.8
36	3.2	2.2
42	2.8	2.3
44	2.4	2.1

Table 2

Quadrilateral Steady State Relay Characteristics
Using $\varphi_L = 45^o$ for two Values of R

Angle φ_{degree}	Critical value of V for R_1 setting in V	Critical value of V for R_2 setting in V
0	2.0	2.9
14	2.8	3.8
18	3.6	4.2
23	3.8	5.2
30	4.0	4.0
36	3.2	3.2
42	2.8	2.8
44	2.4	2.4

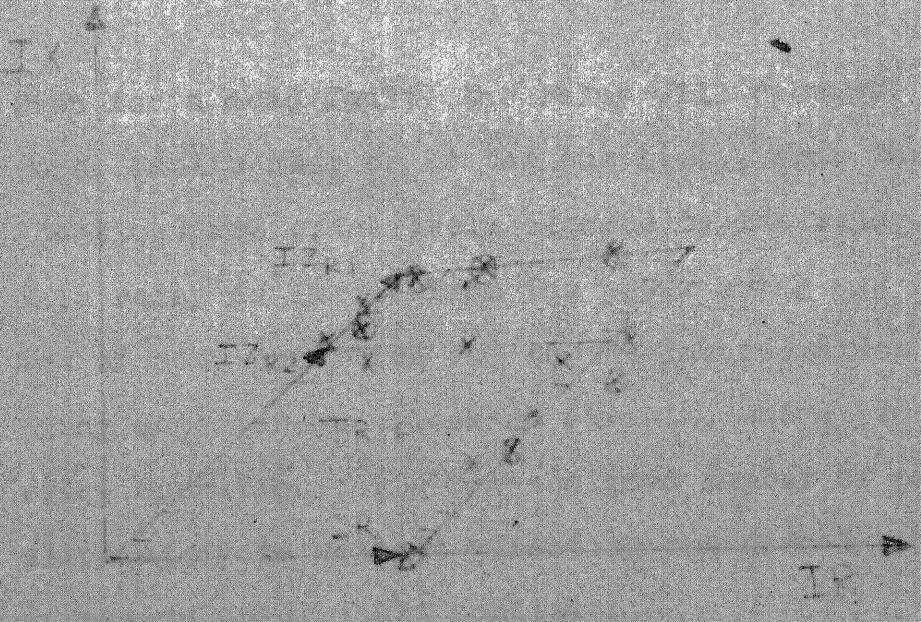


Fig 2.8 Quadrilateral Steady State Relay Characteristic

during $\phi_L = 45°$ for two values of Z_R

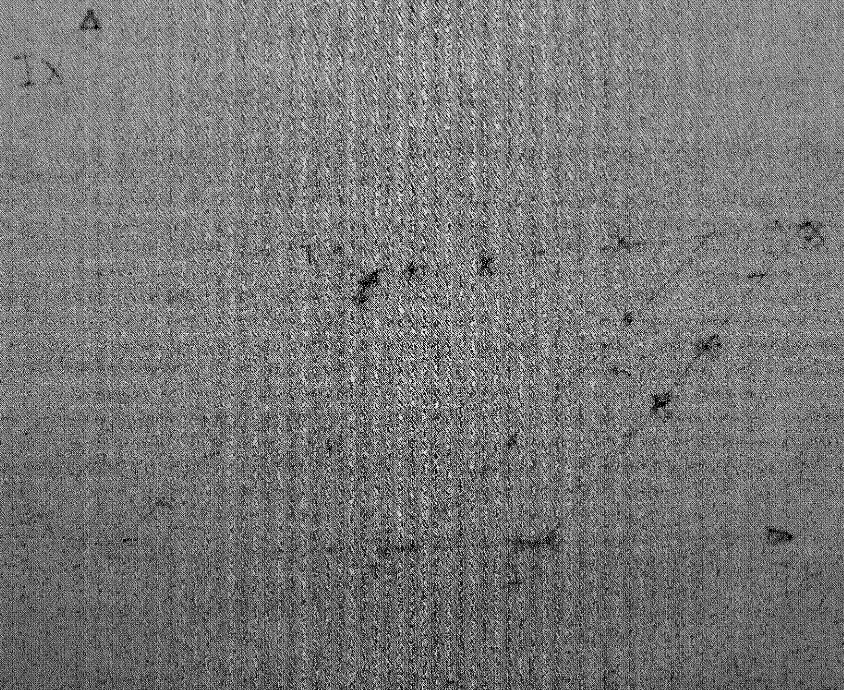


Fig 2.9 [illegible] Steady State [illegible] Ch[illegible]

[illegible] $\phi = 45$ [illegible] of Z_R

(ii) Even for a dead fault, the relay will operate. Therefore, faults near or at the bus (i.e., near the relay location) are effectively cleared by the relay.

(iii) This relay is immune from the power swing and also out of step condition due to the incorporation of power swing detector and blocking circuit, which blocks the relay operation for a pre-assigned number of pole-slipping cycle without affecting the normal relay operation under fault condition.

(iv) The coincidence testing is done with half-cycle time in the first zone operation, which places the relay in the category of high speed relays.

(v) The circuitary of the relay is simple and hence it can be fabricated easily and economically.

It may therefore be concluded, that new static relay is capable of generating quadrilateral characteristics with entirely flexible edges and all the desirable qualities of the relay can be attained using this relay. This relay is ideal for the protection of very long, heavily loaded transmission lines and can be designed for use with either carrier current or microwave pilots.

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APPENDIX

FAULT RESISTANCE

Fault resistance has two components - the resistance of the arc and resistance of the earth. In case of interphase faults, only arcing resistance is involved whereas resistance of the fault path through the tower, tower-footing resistance and earth-return resistance should be added to arcing resistance in case of earth fault.

From Warrington formula, fault-arc resistance can be written as

$$R_F = \frac{50}{I}(V + 47\ ut)$$

where t = time setting of relay in seconds, u = wind velocity Km/hr and V = nominal system interphase voltage, kV.

In case of phase to phase fault, with relay, connected as phase fault element (i.e. using line-to-line voltages and delta currents), measures an arc resistance $R_f/2$ in addition to the line impedance. Similarly apparent fault resistance increases by the factor, fault current divided by the current from the end where relay is installed, in case fault is fed from both end. As earth fault resistance is very high and also ground relays are unaffected by power swings, a conservative estimate is taken for replica arc resistance R for earth faults.